An Evaluation of Alternative Methods of Collecting Sportfishing Statistics for the Northwest Territories

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AN EVALUATION OF ALTERNATIVE METHODS OF COLLECTING SPORTFISHING STATISTICS FOR THE NORTHWEST TERRITORIES

by

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EDITOR'S NOTE

The preparation of the material for this study was done by Interdisciplinary Systems Ltd. Environmental and Socio-Economic Consultants of Winnipeg, Manitoba through a contract with the Department of Fisheries and Oceans, Western Region, Winnipeg, Manitoba.

This study is an edited version of their report to the Department entitled "A Statistical Reporting System for Recreational Fisheries in the Northwest Territories". That study contained chapters outlining departmental fisheries management, biological and economic programs, descriptions of existing data bases and two appendices (one describing native food fisheries and another containing an annoted bibliography of fishery management publications) that have not been reproduced here.

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ABSTRACT

Jacobson J.O., R.D. Cook, and R. Sopuck. 1983. An evaluation of alternative methods of collecting sportfishing statistics for the Northwest Territories. Can. Tech. Rep. Fish. Aquat. Sci. 1180: iv + 18 p.

This study, as a survey of statistical methods for collecting sportfishing data, outlines the basic data requirements for biological and economic fisheries management. The study examines and evaluates delayed data collection systems, on-site data collection systems and hybrid data collection systems with reference to the sport fisheries management requirements of the Northwest Territories.

The study recommends the use of a controlled diary system to collect catch and effort data at remote-access lodge fisheries: a catch/effort census for collecting data for road access fisheries; mail questionnaires for gathering general data and trends in catch and effort for intensive/extensive fisheries, and unstructured field checks for providing general information for extensive fisheries. Finally the study outlines the general methodologies to be followed in order to implement the recommended systems.

Key words: sport fishing; catch/effort data; fisheries management.

RESUME

Jacobson, J.O., R.D. Cook, and R. Sopuck. 1983. An evaluation of alternative methods of collecting sportfishing statistics for the Northwest Territories. Can. Tech. Rep. Fish. Aquat. Sci. 1180: iv + 18 p.

Ce rapport, qui se veut une étude sur les méthodes de collecte de données sur la pêche sportive, fournit les statistiques fondamentales nécessaires à l'aménagement biologique et économique des pêcheries. Le rapport examine et évalue divers systèmes de collecte des données: en différé, sur place et hybrides, et ce, en fonction des besoins d'aménagement de la pêche sportive dans les Territoires du Nord-Ouest.

Le rapport recommande que l'on utilise un carnet où l'on consigne au jour le jour les données sur les prises et sur l'effort dans les pavillons de pêche isolés; que l'on envoie des questionnaires postaux afin de prélever des données générales et relever les tendances du rapport prise-effort chez les pêcheries intensives et de grande envergure, et que l'on effectue un sondage sur les rapports prise-effort dans les pavillons accessibles par la route ainsi que des contrôles libres sur le terrain pour recueillir des données générales sur les pêcheries de grande envergure. Enfin, le rapport souligne quelles méthodes générales adopter pour implanter les mesures proposées.

Mots-clés: pêche sportive; données sur le rapport prise-effort; aménagement des pêcheries.

INTRODUCTION

The Department of Fisheries and Oceans (DFO) is responsible for managing the fish and marine mammal resources of the Northwest Territories (NWT). DFO's management mandate is to protect fish stocks, allocate fisheries resources among alternate users, and evaluate the economic contribution of fisheries resources to the Canadian and regional economies. As a result of increased northern development, the problem of allocating limited fish resources among user groups, some of which are in competition with one another, represents a major challenge to resource managers at DFO.

The NWT include about 3.4 million square kilometers, more than one-third of the total of Canada. More than 1.3 million square kilometers of the NWT are freshwater lakes that support a wide diversity of sport, commercial, and domestic fisheries. Two lakes in particular, Great Bear and Great Slave, support most of the recreational fishing in the NWT. In addition, there are domestic fisheries on both lakes and a commercial fishery exists on Great Slave Lake. Several other lakes, such as those in the Hay River-Fort Smith, Yellowknife, and Inuvik areas, are subjected to an intermediate amount of fishing pressure and resource use conflicts. Finally, a large number of lakes within the NWT are isolated and receive little, if any, fishing pressure of any type.

The orderly development and management of the fish resources of the NWT requires timely and accurate statistics on stocks, yields, effort, economic values, and public attitudes towards the fish resource. A statistical reporting system to provide these data must be flexible enough to accommodate the diversity of fisheries management requirements that exist in the NWT.

This report describes the biological and economic data requirements for the management of the NWT recreational fisheries and reviews the literature on data collection systems. From this base, the report outlines a data collection program to meet existing and potential management requirements and recommends a pilot program to develop and best specify data collection systems for the sport fisheries in the territory.

DATA REQUIREMENTS

CLASSIFICATION OF SPORT FISHERIES

The fisheries of the NWT have been classified into three general types based on the level of management required. These management categories are intensive fisheries, intensive/extensive fisheries, and extensive fisheries (R. Peet personal communication). The categories, based on present levels of exploitation, are therefore subject to change if developments such as road access change the use of the fishery.

Intensive fisheries

Fisheries that meet one or more of the following criteria are classified as intensively managed lakes:

- fisheries where any combination of commercial, sport or domestic uses are straining the capacity of the fish resources;
- any single use fishery that may be exploited to the point where there is excess fishing effort;
- fisheries that have existing or imminent resource use conflicts, such as between sport and commercial fishermen.

Intensive fisheries having any of the above characteristics have management problems that require immediate action and therefore require accurate and timely information. Intensive sport fisheries are usually associated with either high density road access, high density remote access lodges, or a combination of the above. Examples of intensive fisheries in the NWT are shown in Table 1.

Intensive/extensive fisheries

Fisheries that meet one or more of the following criteria are classified as intensive/extensive fisheries:

- where there is an established pattern of use by commercial, sport, or domestic users that does not currently strain the capacity of the fish resources.
- where planned or anticipated increases in use could exceed the capacity of the fish resources.
- where resource use conflicts do not currently exist and are not anticipated to be a problem in the immediate future.

The same biological and economic information is required for intensive/extensive fisheries as for intensive fisheries; however, the information does not have to be collected as frequently and may not have to be as precise. Examples of lakes in this category are also included in Table 1.

Extensive fisheries

Fisheries that meet one or more of the following criteria are classified as extensive fisheries:

- where there are commercial, sport or domestic users, but where the level of fishing effort is very low in relation to the capacity of the fish resources.
- where there are no present concerns that anticipated expansion of the fishery will exceed the capacity of the fish resources.
- where resource use conflicts do not currently exist and are not anticipated within the next 5 to 10 years.

Extensive fisheries only require the documentation of the locations, type, and general levels of sport fishing. Examples of extensive fisheries include most lakes in the District of Franklin and any lakes in the Keewatin or Mackenzie Districts that do not have lodge or community access.

CLASSIFICATION OF NWT FISHERIES BY SAMPLING REQUIREMENTS

The management classification of NWT fisheries described above is designed to identify the types of information required to manage the fishery and the frequency with which the data should be collected. The design of data collection programs requires the further classification of each of these management classifications, based on the types of sampling techniques that will be required to collect data on yield and effort. Slightly different data collection techniques will be required for each of the following categories.

Lodge-related fisheries

Lodge-related fisheries are defined as remote access fisheries where anglers are under the "control" of the lodge operator. Outcamps, such as those on the Tree River, are also considered lodge-related fisheries. Lodge-related fisheries are characterized by having a well-defined and controlled user population.

Road-access fisheries

Road-access fisheries are defined as any fishery that has ground access. Examples of these fisheries include the Yellowknife and Hay River areas and the community sport fishery at the Sylvia Grinnell River. These fisheries are characterized by having one or more ground access points, with an undefined and uncontrolled user population.

TYPES OF DATA

The objective of "ensuring optimal social and economic benefits ... from the utilization and conservation of fish ... in the Arctic" (Cauvin 1981) implies a degree of complimentarity between biological and economic analyses. In this regard, many of the data requirements are identical.

Biological information

The basic types of data are defined as follows:

- STOCK: Total numbers or weight of fish present in the waterbody at a given time. Fish stocks must be monitored periodically to determine numbers and stock composition (age and length distributions) in order to assess the effects of exploitation.
- CATCH/UNIT EFFORT: Total catch divided by total effort. These data will generally be required on an annual basis for selected species for selected lakes. It may also be required for selected areas within lakes.

Stock and harvest are basic biological parameters needed to manage fisheries. Stock assessments require estimates of such factors as length, weight, age and reproductive status. Estimates of harvest, effort, and catch/unit effort are used in conjunction with stock assessments to monitor the exploitation rate of the fishery. They are also used in conjunction with age and length distributions to monitor the effects of exploitation of populations, and as management indicators of the quality of the fishery. DFO has programs in place to conduct biological stock assessments of NWT fisheries as required. This study deals with methods of collecting catch, effort, and catch/unit effort statistics for the sport fisheries in a manner compatible with, and complementary to, the existing stock assessment program.

Economic information

There is a close relationship between the data required to meet biological management objectives and the data required to meet economic management objectives. In addition to the data defined above other economic data are needed on a periodic and specific study basis to estimate the economic benefits and costs associated with the recreational fishery in the NWT. These economic benefits and costs, generated at both primary and secondary levels, have been defined for the purpose of this study (Cauvin 1982) as:

- PRIMARY BENEFITS: These benefits are the "final" demand for the recreation use of the fisheries resource. Final demand can be interpreted as the interface between the final consumer - the angler - and the supplier of the product - in this case the public sector. Because access to recreational fishing has traditionally been effectively non-priced, the "final" demand or primary benefits are measured as the willingness of anglers to pay. It therefore may incorporate two elements; what they actually pay (i.e. nominal licence fees) and what they would be willing to pay if they had to.
- PRIMARY COSTS: These costs include the public supply costs and the opportunity costs that arise as a result of allocating fisheries resources to recreational rather than commercial or domestic fishing.
- SECONDARY BENEFITS: This is defined as the demand for goods and services such as food, lodging, and gear associated with recreational fishing.
- SECONDARY COSTS: The overall costs of providing the ancillary goods and services such as food, lodging, and gear are defined as secondary costs.

In developing economic statistics for the sport fishery, the initial focus should be on the primary benefits and costs of those portions of the sport fishery that require intensive management. These benefits and costs could be

analyzed through the development of biological production functions, conversion of the biological production functions to economic yield functions, and the calculation of the net value of the fishery (Cauvin 1982).

The biological production functions in this methodology consist of establishing the relationship between population size, annual yield, fishing effort, and harvest success per angler day. This is exactly the same data required for biological management. The use of one set of data to meet both biological and economic management objectives allows administrators to optimize allocation of personnel and resources to achieve specific management objectives (Gordon et al. 1973).

Because there is no market system associated with recreational fishing, the development of economic yield functions for sport fisheries has always been a particularly troublesome problem. Some conservationists and scientists have opposed the use of economic techniques for placing a dollar value on nonmarket resources (Seckler 1966). Two techniques, based on the willingness-to-pay concept, have been developed to compare relative benefits of resources and allocate limited resources among users. These have become widely accepted techniques for estimating the net primary benefits of recreational fishing (McConnell and Norton 1975; Dwyer and Bowes 1978) and a number of other resources (Kreutzwiser 1981; Pearse 1968). The first willingness-to-pay method, derived from travel costs, is based on estimates of demand and value that are generated from observed participation or visitation rates. Travel costs in this method serve as a proxy for price. The second method, direct surveys, involves asking fishermen the maximum amount they would pay for the right to use the resource (equivalent variation) or the amount that would be required for them to forego the right to use the resource (compensating variation).

If the demand curve calculated from this willingness-to-pay data is interpreted as a marginal benefit function, the net value of the fishery can be calculated as the total benefit minus the total primary costs. The primary costs include the public supply costs as well as the opportunity costs associated with allocating fisheries resources to anglers.

DESCRIPTION AND EVALUATION OF DATA COLLECTION SYSTEMS

Various methods of collecting fisheries data have been reported in the management and scientific literature over the past few years. These methods, designed to collect the biological and economic data requirements have taken a variety of forms, including: active and passive creel censuses, voluntary creel censuses, licence reporting stubs, species permits, industry logs, fishermen diaries, mail questionnaires, and telephone surveys. Reporting methods used by 13 resource management agencies in the western United States prior to 1974 are summarized in Table 2.

All of these methods can be characterized by the time at which the data is collected in relation to the time at which the actual fishing experience occurred. These differences will influence the effectiveness of the methods. Mail questionnaires and telephone surveys are delayed data collection methods in which users are often questioned several months after the fishing occurred. Active creel censuses are an immediate, on-site data collection method. For the other methods, the delay between the fishing experience and the time the data is collected varies between these two extremes.

DELAYED DATA COLLECTION SYSTEMS

All sample surveys contain a certain proportion of errors; some of them are sampling errors and some nonsampling errors. Mail questionnaires and voluntary returns of creel census reports, logs, diaries, and permits all suffer from nonresponse bias. Erdos and Morgan (1970) as cited [on p. 444] in Filion (1980) reported that the Advertising and Research Foundation recommended that an 80% or better response rate be targeted for mail surveys in order to minimize the problem of inaccurate population estimates. This level of response yields a rate of non-response that is in line with the rate of substitution for well-conducted personal interview studies. At this level, it is thought that the precision of estimates will converge for the two methodologies. Standard references, such as Cochran (1977), on the principles and technique of sampling describe how to identify and minimize these errors. Filion (1980) reviewed the literature on nonsampling errors and focused on techniques to identify and minimize nonresponse and response biases in human surveys.

There is considerable evidence from a variety of scientific disciplines that differences may exist between the true answer to a question and the respondent's answer to it. Research in experimental psychology indicates an inverse, exponential relationship between an individual's ability to retain information and the time elapsed since the event occurred. The ability to recall events may be influenced by motivation or interest, emotions or perceptions during the event, and the frequency of use or recurrence (Hilgard and Atkinson 1967). Cannell et al. (1977) concluded that, as the time between the event and the questioning increased, (a) there was increased under-reporting of information about that event, (b) events important to the respondent were reported more completely and accurately than those of less importance, and (c) reporting of an event was likely to be distorted in a socially desirable direction.

Ashraf et al. (1975) as cited in Kazes (1980) reported a 25.83% increase in the total number of trips in the Canadian Travel Survey using a three month rather than a four month recall period. Kazes (1980) reviewed the problem of recall bias in several U.S. government surveys. The U.S. Bureau of the Census conducted a pretest in Washington, D.C. to study recall abilities of crime victims. Eighty-six percent recalled the incident within

a three month recall period 78% recalled it in six months, and 70% recalled it within 12 months. The U.S. Bureau of Labor Statistics has tested the accuracy of recall for purchases of durable goods. Large items were under-reported by 10% for a three month recall period, by 41% for a 4-6 month recall period and by 47% for a 7-12 month recall period. In addition, there was a 54% increase in average reported expenditures using three month vs six month recall periods. The National Crime Survey, conducted by the Bureau of the Census from 1973 to 1975, reported 16% to 30% more crimes for a three month recall period than for a six month recall period. A health interview study conducted in 1967 by the Department of Health, Education and Welfare found that 98.6% of known accident victims recalled the incident within 3 months, 90% recalled it within six months, and only 77.7% recalled it within 12 months.

A number of studies that investigated recall and nonresponse bias in fish and wildlife surveys found that instead of under-reporting, many of the surveys over-reported harvest. This may be partially due to the prestige factor reported by MacDonald and Dillman (1968).

Hiett and Worrall (1977) studied the ability of marine recreational fishermen to estimate the nature of their catch and to recall their total catch and effort over a period of time. This study showed that:

- Fishermen were unable to identify species of fish with a satisfactory degree of accuracy.
- Fishermen made errors in estimating weight and length of fish. Weight tended to be overestimated for smaller fish and underestimated for larger fish. Length tended to be underestimated, regardless of the size of the fish. In addition, 22% incorrectly reported the number caught.
- Recall of specific fishing dates was poor, although the total number of fishing trips was often estimated with reasonable acccuracy. Fishermen were able to report dates for trips further back in time than for which they were able to give detailed fishing information. By the end of 60 days, fishermen were unable to provide detailed information on approximately one-fourth of their reported trips.
- Fishermen tend to overestimate by a considerable degree the effort expended for fishing trips.
- Fishermen tend to overestimate by a considerable degree the total catch for their fishing trips.

Hiett and Worrall (1977) concluded that, to improve accuracy of marine recreational fishermen survey, as much information as possible should be collected from an on-site survey, and that the recall period for reporting trips should be no longer than 60 days.

Charbonneau (1980) reported that as a result of the above work and other experience with the National Survey that a modified two-survey approach is now used for the marine recreational fisheries survey. This modified approach uses a telephone survey to collect data on enumeration of fishermen, trips by mode of fishing, trips by geographic locations and area fished. The approach uses an intercept survey to collect data on residence of fishermen, catch per trip, and catch by species (Deuel 1980).

Simpson and Bjornn (1965) compared results obtained from postal questionnaires, permits returned voluntarily, random samples of permits, and check stations for steelhead trout harvest in Idaho. Postcard questionnaires had been used to estimate the statewide annual harvest of chinook salmon and steelhead trout since 1954. While these estimates were statistically precise (95% CI=± 10% of estimate), the high harvest rate that resulted from these estimates was unrealistic, and questionnaire estimates of harvest have ranged from 1.8 to 3.4 times the number of fish counted at check stations. Starting in 1962, each angler fishing for steelhead was required to have in their possession a steelhead permit to record the date and place of each steelhead caught. In 1964, harvest estimates were compared to check station data for the South Fork of the Salmon River. Estimates based on a random sample of permits were very close to check station values (737 vs 726). The estimate from voluntarily returned permits was 1.4 times the random sample estimate, and the questionnaire estimate was 2.4 that of the random sample. Nonresponse bias only accounted for 16% of this overestimate. Consistent with other studies, a much smaller percentage of anglers in the random sample group had fished and caught fish, and they had a lower mean annual catch than those in the voluntary return group.

Carline (1972) and Jones et al. (1977) reported biased results from passive creel censuses compared to active interviews. In an attempt to estimate the harvest of brook trout in Wisconsin, Carline (1972) provided self-addressed postcards to fishermen on-site, with a request to complete and return the form. The results demonstrated a significant positive bias in the postal survey data, with catch rates from the postal returns double the catch rates from anglers interviewed on-site. Only 50% to 60% of the postcards were returned, and the discrepancy between the postal survey data and the on-site interview data was attributed to a failure to return postcards by unsuccessful anglers and anglers who caught only a few fish to return postcards. He also suggested that multiple reporting on postal cards may have contributed to the bias. He concluded that the length of time the census covers, the number of waters involved, the number of species in question, and the proportion of surveys returned were all important considerations in determining the reliability of postal survey data.

Jones et al. (1977) comparing a voluntary registration system with direct interviews on a Texas pond fishery, found that respondents to the passive survey reported only 17% of the number of fish estimated by the active survey. The weight of fish reported in the passive survey was, however, nearly 70% of the weight estimated by the active survey. They concluded that these

discrepancies probably resulted from the tendency of fishermen to report only catches of large fish, to overestimate the size of fish taken, or both. The passive survey also provided an estimate of total fishing pressure that was less than 10% of results derived from the active survey.

A number of other researchers have also found biases in postal surveys of fisheries catch and effort. Jensen (1964) compared postal surveys with random samples of fishing vessels and with log books of party boats. He found that harvest estimates from the postal surveys were three to five times higher than harvest estimates derived from the on-site samples.

For the past 13 years, the Michigan Department of Natural Resources has conducted statewide mail surveys of licensed anglers to estimate sport angler effort, catch, and participation. During this period, numerous on-site creel censuses have also been undertaken to assess management actions and to provide an in-depth assessment of unique and/or economically important fishing waters. Department personnel recognized that both methods were vulnerable to various biases; however, they concluded that their mail survey estimates for both catch and effort generally are two to five times as high as those obtained from an on-site creel census (Gayle Jamsen, personal communication).

Murphy (1954) found that the rate of return of the postal surveys influenced the final results of his surveys. Early respondents to his survey reported a considerably higher catch per unit effort than late respondents on the follow-up returns. He finally received total questionnaire returns of 84%to 91%, and concluded that at the final higher level of return he could find no evidence of bias in the postal survey.

The DFO, Western Region, attempted a voluntary questionnaire survey in the Yellowknife and Hay River areas in 1979 to determine locations fished, number of fish caught and retained, hours fished, and fishing quality (Falk 1981). Only 16% of the questionnaires handed out were returned. Although the author noted that estimates of catch per angler and catch per angler-hour compared favorably with those determined previously using creel censuses, he also noted that the catch per angler tended to be higher for the questionnaire method, which is consistent with other studies using passive or voluntary creel censuses. Falk (1981) concluded that although the questionnaire may provide a broad picture of sport fishing in the study area from which to develop management strategies, it does not provide the information needed to determine total fishing effort and total harvest.

The Manitoba Department of Natural Resources attempted a voluntary creel census at five remote lodges (Fishing, Sasaginnigak, Aikens, Dogskin, and Moar lakes) in 1974 (W. Hayden, Manitoba Department of Natural Resources, 1495 St. James St., Winnipeg, personal communication). Recording forms were distributed to lodge owners who were asked to distribute them to anglers. Anglers were asked to complete the forms after fishing and to deposit them in a container in their cabins. Only about a dozen forms were completed and returned. The poor response was attributed to the lack of a person on-site who was responsible for ensuring that the program worked, and an inadequate education program to impress upon lodge owners and anglers the importance of the program.

The DFO, Western Region, tried a similar type of voluntary creel census at Great Bear and Bear Island lodges (with some returns), and at Kasba Lake (with very few returns). Neither of these voluntary programs was considered to have provided adequate information on the fishery.

The state of Alaska has used a combined postal survey and creel census program since 1977 to obtain estimates of effort and harvest by fishery and by species (Mills 1981). The postal surveys consist of repeated mailings of questionnaires to random samples of Alaskan sport-fishing licence holders. Creel censuses consist of on-site interviews of random samples of sport fishermen. The postal surveys provide estimates for all the fisheries, while the creel censuses are only used on major, selected fisheries to provide validity checks. The 1980 postal survey, which involved 12,000 questionnaires with two follow-up mailings, produced a total return of 66%. Mills (1981) concluded that the 1980 surveys continued to provide an effective method of estimating statewide effort and harvest for major Alaskan fisheries.

Since the early 1950's, the DFO, Pacific Region, has relied on estimates of sport catch made by fisheries officers using a variety of judgemental techniques (MacGregor 1982). During the mid-1970's, several studies (i.e. Argue et al. 1977) indicated that the annually collected statistics on sport fishing catch and effort in DFO's Pacific Region were underestimating the actual values by as much as two to four times. Consequently, the traditional techniques were abandoned, and in mid-1979 the Tidal Sport-fishing Diary Program was instituted (MacGregor 1982).

The diary program, which is still in operation, consisted of an initial random questionnaire survey to British Columbia residents. This questionnaire is used to collect information on average days fished and average catch. The data is used to quantify nonresponse bias from the diary fishermen returns; it is not used to estimate total catch and effort. A telephone follow-up is used to correct for the nonresponse bias to the questionnaire survey.

A selected number of sports-fishermen who agree to keep a daily record of fishing activity are sent a total of four diaries during the year. Diaries are mailed in for analysis quarterly, and are returned to the fishermen for their personal use when the data has been tabulated. Anglers are requested to record fishing activity as it occurs, including the date of each trip, the number of other anglers in the party, target species, area fished, type of fishing, and the size categories of the fish kept and the total caught. Instructions and

maps of the major fishing areas are included in the front of the diary.

Several problems still exist with the diary data. In 1980, about 75% of the people sampled responded to the postcard questionnaire. Of these respondents, 75% agreed to keep a diary and about one-half of this group returned their diaries every quarter. Telephone reminders were used to contact fishermen who had not returned their diaries. Less than one-third of the diary fishermen who returned their books actually went fishing in 1980, even though they intended to at the beginning of the year. The telephone reminders indicated that anglers who did not return their diaries usually had not gone fishing. As a result the diary program still contains a response bias in that anglers who keep and return diaries fish more often and are more successful than other anglers.

In the 1980 diary survey, 39% of the anglers caught no fish, and 10% of the anglers caught 54% of the total salmon catch. The major concern with the diary program estimates is the high catch per unit effort obtained: approximately double that of any other study, including the preliminary questionnaire. A portion of this overestimate was attributed to respondents overreporting individual catch by using boat totals. This is being alleviated by asking for boat rather than individual catches in subsequent surveys. Most of the overestimates were caused by respondents who underreported the number of days fished. It was concluded that anglers tended not to report fishing trips that were unsuccessful. The 1982 program therefore placed more emphasis on encouraging participants to report unsuccessful days by improving the design of the diary and the accompanying instructions.

MacGregor (1982) concluded that despite the small number of fishermen involved, the diary program produced reasonable estimates of annual catch. Solutions to the low estimates of effort are being tested. A major attraction of the diary program is the opportunity to obtain adequate and inexpensive estimates of sport catch and effort without placing additional burdens on field staff.

Conclusions

It is apparent from the literature that techniques using delayed data collection methods can suffer from significant nonresponse and recall bias.

Nonresponse is a universal problem associated with surveys that require voluntary responses from the sampled population (see Cochran 1977). Most of the authors reviewed for this study (Carline 1972; Jensen 1964; Simpson and Bjornn 1965; Murphy 1954) found that the rate of return of voluntary questionnaires influenced the final results of their surveys by several hundred percent. Murphy (1954) was the only author who could find no bias in his final results; however, his total questionnaire return rate was 84% to 91%, unusually high for resource user surveys. Statistical techniques are available to provide estimates of the nonresponse portion of the sampled population (Cochran 1977). Filion (1980) recommended combining two approaches to minimize problems of nonresponse; maximize response, and correct for bias by extrapolating across successive mailing waves or weighing responses to follow-ups.

Recall bias is a major problem of delayed data collection surveys that must be taken into account in any decision on methodologies to collect statistics on catch, yield, effort, and catch per unit effort. Standard techniques are not available to address the nature and magnitude of the recall bias. Two mathematical techniques have been proposed to adjust for recall bias in post-season game harvest surveys; however, Filion (1980) suggests that both techniques have limitations and should be used with caution. He suggested that experimentation with shorter recall intervals, panels, or even the diary method might yield some effective solutions.

Even if the recall bias can be accurately defined, the cost of providing sound statistical estimates of the data correction factors could exceed the cost of collecting the original data. Because of the nature of magnitude of the recall bias problem, we concur with Hiett and Worrall (1977) that as much information as possible should be collected from on-site surveys, and that the recall period for reporting of trips should be as short as possible, preferably no longer than 60 days.

Voluntary or passive creel censuses, if conducted essentially on-site, could reduce the recall bias problem. They do, however, suffer from a major non-response bias (Falk 1981; Carline 1972; Jones et al. 1977). This problem, combined with the fact that voluntary or passive creel censuses are not directly capable of providing information on total harvest or total effort, makes them unsuitable as the major component of a data collection system in the NWT.

The diary system as described by MacGregor (1982) for the tidal sport fishery in British Columbia has some advantages over the methods described above. Not the least of these is the opportunity to obtain adequate and inexpensive estimates of sport catch and effort without placing additional burdens on field staff. The design could theoretically eliminate the recall bias problem; however, the existing implementation of the diary program for the tidal sport fishery still contains a number of potentially serious biases due to poor return rates and the small number of active anglers participating.

Consequently, we recommend that on-site surveys, rather than delayed data collection surveys, be used to collect lake-specific catch, yield, effort, and catch per unit effort information for the management of the road-access recreational fisheries in the NWT. Existing diary programs such as the Tidal Sportfishing Diary Program are not directly applicable to the NWT, primarily because of the problem of allocating diaries to sport-fishermen when approximately 50% of the anglers each year are new (Topolniski 1975), and the problem of collecting adequate data on yield and effort for specific water bodies.

Because of the potential advantages and cost savings of a diary system, however, we recommend a modified controlled diary program for the remote access lodge fisheries. The proposed system would essentially eliminate the bias problem in the tidal diary program, eliminate the diary allocation and specific area data collection problems, and provide an effective system for collecting catch, yield, effort and catch per unit effort statistics.

It is not uncommon in resource management to monitor wildlife populations for general management purposes using surveys that are known to be consistently biased. Mail questionnaires, therefore, may be useful to monitor general trends and changes in catch and effort for portions of the road-access recreation fishery if the response and recall biases can be held constant. Such a survey of sport fisheries in the NWT could provide trend information for long-term management, and could be used to identify site-specific areas requiring the intensive, accurate surveys recommended above.

ON-SITE DATA COLLECTION SYSTEMS

The concept of "creel censuses" has been used by fisheries managers for more than half a century to collect management information on recreational fisheries. These surveys have traditionally been used to collect data on total fishing effort, total catch, catch per unit effort, and species composition in the catch (Moyle and Franklin 1957; Erman 1972; Gard and Seegrist 1972; Farr and Blake 1979; Panek 1981). They have also been used in recent years to determine fishermen's attitudes, user patterns, and socio-economic attitudes towards development projects (Sinclair and Morley 1975). The term creel census is used in the generic sense in the following discussion to describe any direct interview survey of the recreational fisherman, including intercept, location, on-site or creel surveys.

Mottley and Embody (1940), who evaluated several creel census techniques, emphasized the importance of any partial creel census meeting the criteria of representativeness, adequacy, and cost. Carlander et al. (1958) who also reviewed existing creel census methods, stressed the importance of applying detailed sampling techniques to creel surveys and emphasized that "only when sampling is done according to some statistical scheme can reliability of the data be measured and certain biases be avoided".

A number of physical and external factors can influence the outcome of a creel census, including the weather, irregular concentrations of fishing effort, and variations in availability of species (Best and Boles 1956; Malvestuto et al. 1979).

Sinclair and Morley (1975) described a number of other factors in the survey that could cause erroneous results due to the effects of disproportionate representation. The factors include poor questionnaire design, interviewer error, nonrandom sampling, improper survey design, and response bias. In addition, they pointed out that user participation bias can occur because certain segments of the population have an excessively high probability of being included in the sample. This bias results from some persons staying longer at the site on each visit than others (length of stay bias) or some people visiting the site more often than others (frequency of use bias). Both forms of bias can be eliminated if reliable information on the probabilities of selection in the sample survey can be established. This requires that an analyst have an independent estimate of the target population and a reliable estimate of the probability distribution of the survey interviews over the activity groups. Malvestuto et al. (1979) used a multiple regression model of climatic variables to explain some of the variation associated with creel survey estimates of fishing effort, and to provide a means of optimally allocating sampling effort prior to implementation of a survey.

Robson (1960) presented the first detailed creel census procedure for achieving unbiased sampling and estimating of fishing success, total effort, and total harvest using a stratified random sample. He subsequently adapted this procedure to a roving creel census (Robson 1961). Regier (1966) adapted Robson's method to a field survey, and Hayne (1966) and Malvestuto et al. (1978) have incorporated nonuniform probability sampling into the stratified random approach.

A complete census of the fishermen on a particular lake or river over the complete fishing season is usually impossible due to limitations on manpower and funds. Most creel censuses are therefore designed as sample censuses, and a ratio-type method of estimation is employed to estimate the total catch (Robson 1960). This method consists of applying an estimated catch rate to the estimated total effort. It is based on the fact that the number of fish caught per fisherman is correlated positively with the number of hours fished, and that total fishing time by all fishermen can be estimated from easily obtained random counts. The method provides a statistically unbiased ratio-type estimate of total catch and total fishing effort and of the sampling error variance of the estimators.

Robson (1961) modified this method to accommodate the "roving creel census" in which the enumerator moves through the fishing area interviewing fishermen as they are encountered. Some unique problems associated with the roving creel census are that the sample size depends on the number of distribution of fishermen, the sample is systematic rather than random, the probability of interviewing a given fisherman depends on how long he fishes, and usually only incomplete information is available from each fisherman. The major weakness of the roving creel census using incomplete fishing trips to estimate total catch is that the bias of estimation depends on the basic nature of the stochastic fishing process which, in general, is not known (Thompson 1976). The only sure way to make the creel census distribution-free is to station interviewers at access points to obtain information on completed trips.

Malvestuto et al. (1978) described an application of the roving creel survey with nonuniform probability sampling. The paper serves as an example of how a statistically based creel survey can provide information required for fishery management as well as information needed to evaluate the design. Their method is evaluated by testing the assumption that the catch per unit effort for incomplete fishing trips is an unbiased estimator of the catch per unit effort for complete trips. The basic features of the application of nonuniform probability sampling to the roving creel census are:

- The entire period for which the fishery is to be surveyed is divided into time blocks which should contain a similar amount of expected fishing pressure.
- Each time block is divided into sampling units such that all of the fishing time within a block is contained within the sampling units and the units do not overlap.
- Sampling probabilities proportional to the amount of fishing expected are assigned to the sampling units. The sum of the probabilities within any block is 1.0.
- Sampling units are randomly chosen within each block on the basis of the assigned sampling probabilities.
- Sampling on the water body is comprised of counts and interviews. Counts should be as instantaneous as possible, and the interview should be representative of the water body being sampled.

Malvestuto et al. (1978) concluded that this method appeared capable of detecting changes in the quality of fishing small enough for management purposes. They stressed the importance of measuring precision of the survey so that the efficiency and sensitivity of the survey design would be evaluated.

Conclusions

After describing the problems associated with recall bias, we concluded that on-site surveys are required to collect statistically sound, site-specific catch, yield, and effort data. Robson (1960, 1961) and Malvestuto et al. (1978) have adequately described the overall structure of a creel census that will provide sound statistical estimates of total yield, total effort, and catch per unit effort. Robson (1961) pointed out problems that can be associated with incomplete interviews during roving creel censuses and Malvestuto et al. (1978) provided a mechanism to test for these problems.

Consequently, we have recommended a creel census for road access fisheries, which will be described in detail in a later section that is a combination of the above two approaches. It uses an intercept census to determine catch per unit effort as suggested by Robson (1961), and incorporates some of the temporal and spatial stratifications suggested by Malvestuto et al. (1978). The design eliminates the length of stay and frequency of visit bias discussed by Sinclair and Morley (1975).

HYBRID DATA COLLECTION SYSTEMS

The literature clearly identifies major problems using delayed data collection techniques to collect accurate site-specific catch or yield information. These problems may be less severe if these techniques are used to collect effort statistics, particularly if the time interval between fishing trips and the questionnaire is limited (Hiett and Worrall 1977).

Since effort is the most difficult component of the on-site creel census to collect, a combination system using a mail questionnaire to collect effort data and an on-site survey to collect catch per unit effort data could be considered for the road access fisheries. There are however, four major problems associated with implementing this combined system to collect required recreational fishery effort data in the NWT: (1) nonresponse bias; (2) recall bias; (3) sample frame, and (4) timeliness of information.

The nonresponse bias is a standard problem of mail questionnaires. Previous information for the NWT (Topolniski 1975) indicates that relatively good response rates might be expected from a simple questionnaire; however, follow-ups and sub-sampling of the nonrespondents will be required since, as noted earlier, effort and response appear to be correlated in similar surveys. Recall bias for effort is related to the timeliness of the questionnaire and the amount of information requested. It would not be reasonable to ask potential respondents to provide any more detail than for days fished during the survey period. If information was required on catch per angler hour, a separate survey would be required to provide a statistically sound estimate of mean angler hours per day.

Although there are a limited number of fishing licence vendors in the NWT, the problem of identifying a proper sampling frame to collect effort data for a particular species on a particular lake during a given year is nontrivial. The current licensing system does not lend itself to defining such a specific sampling frame and a very large number of questionnaires would be required to achieve adequate sample size for a particular lake or river.

Finally, the timeliness of the questionnaire is critical to minimizing recall bias. The existing licence system is currently not capable of providing the data in the time required (Topolniski, personal communication). Even if it were modified, it is questionable that it could be timely enough (e.g. within 60 days of fishing season) to limit recall bias to an acceptable level.

Conclusions

Mail-out questionnaires with their attendant problems of response, recall and timeliness are a relatively poor method of providing statistically sound, site-specific catch and effort data. Nevertheless carefully designed mail questionnaires may be an appropriate method of providing general and trend effort data on sport fisheries on either a territorial or sub-territorial (regional) basis.

RECOMMENDED DATA COLLECTION SYSTEMS

The NWT contains a wide diversity of sport fisheries. Two classification systems have been developed during this study to characterize these fisheries. The intensive, intensive/extensive, and extensive classifications characterize the resource use pressure on the fishery and, indirectly, the frequency and type of management information that is required. The lodge-related and road-access classifications characterize the type and geography of the fishery that directly influence the type of data collection program required.

These two classifications were integrated into the analysis of the sport fishery data requirements for the NWT. Based on this analysis, a three-tier statistical reporting system, shown in Fig. 1, is recommended to provide the necessary management information.

The recommended reporting system utilizes four different types of data collection systems: (1) unstructured field checks are recommended for providing general information on extensive fisheries; (2) mail questionnaires are recommended for gathering general data and monitoring trends in catch and effort for intensive/extensive fisheries; (3) a modified, controlled diary system is recommended for collecting statistically sound, site-specific information on the remote-access lodge fisheries, and (4) a catch/effort census is recommended for collecting statistically sound, site-specific information on the road-access fisheries.

We recommend that the current system of unstructured field checks continue to serve as the data collection program for the extensive fisheries of the NWT. Experienced field personnel are familiar with their region and, through their public contacts, know what is going on with the resource and its users. Collection of general information on type and amount of use, and trend information on effort, success rates and catch can be integrated with public information and law enforcement functions with minimal additional costs.

We recommend that two data collection systems be used for the intensive/extensive sport fisheries. A system of mail questionnaires should be instituted to collect general information on the intensive/extensive sport fisheries and to monitor trends in important biological and economic management parameters. This questionnaire system should be designed for periodic, annual or special use, with a sample frame stratified by region or area of recreational fishery. This questionnaire system will require a redesign of the NWT licence system and will require an administrative and sampling design to minimize and make consistent the response and recall bias inherent in such a system. The results of these mail questionnaires should be used to facilitate long-range, regional management decisions and to identify areas where accurate site-specific information is required.

For intensive/extensive sport fisheries that have been identified through mail questionnaire data or other sources as requiring more detailed information, we recommend using one of two systems, depending on the type of fishery. A modified diary program is recommended to collect site-specific data on remote access fisheries, and a catch/effect census is recommended to collect site-specific data on road-access fisheries when required. Application of these data collection systems is described below. Both systems provide the mechanism to collect site-specific biological data, catch and effort data, and economic data.

It should be noted that the two data collection systems recommended for the intensive/extensive fisheries are not alternative methods of collecting the same information; they are separate and complementary systems. Alternatives to the mail questionnaires for collecting general information and monitoring trends include the unstructured field checks recommended for the extensive fisheries, or systems using report forms, permits or diaries.

While structured field checks are useful for general information they are not capable of providing unbiased or consistent data with which to monitor trends. Report forms or permits issued with a licence are a traditional way of collecting resource use or harvest data. Their advantages are that they have a relatively high public acceptance and very low cost per response (<$1.00 compared to $1.00-$3.00 per questionnaire response) (Aney 1974; Jamsen 1971). The report forms or permits have an uncontrolled response for information on specific areas; and they suffer from a very low response rate, high nonresponse bias, and varying rates of recall bias. In addition, they are primarily designed to collect harvest and effort information and are not well suited for collecting other data such as attitudes or economic data. This lack of flexibility, combined with relatively large and uncontrollable biases, precludes their consideration as viable alternatives to mail questionnaires for collecting general information and monitoring trends for the intensive/extensive sport fisheries. The diary system has many of the same advantages and disadvantages of the reporting forms and permits discussed above. Because of this, and because of the large turnover in NWT licence holders, the diary system is not a viable alternative to the mail questionnaire for intensive/extensive fisheries.

For the intensive sport fisheries we recommend that a modified and controlled diary program be used annually to collect site-specific data on the remote access fisheries, and that a catch/effort census be used to collect site-specific data on the road access fisheries. The site-specific data collection system for the intensive fishery, therefore, differs from the intensive/extensive fishing in the frequency of application of data collection. Since both systems we are recommending for the intensive fishery include the mechanisms for collecting site-specific biological, catch and effort, and economic data, an annual or periodic mail questionnaire is not required. Mail questionnaires can be used, however, in special circumstances where other information such as user attitudes or demographic characteristics are required.

MAIL QUESTIONNAIRES

A mail questionnaire can be designed and administered such that it provides trend data on territorial and regional sport fisheries. Four major administrative and analysis problems associated with such a survey must, however, be overcome for the mail questionnaire to be a useful and reliable management tool.

The present licence system is not capable of providing an adequate sample frame. Licences frequently do not contain adequate address information and are completed in a manner that makes most of the information unrecognizable and unusable. The content and design of the licences must be reviewed and a revised licence form developed that enables respondents to write legibly and to provide the required information. The Manitoba Wildlife Certificate is a useful starting model. An administrative system should also be developed that penalizes vendors for any spoiled licences.

The current licence system is not capable of providing a timely sampling frame; delays of between 18 and 24 months now exist between the time the licences are sold and the final compilation of the licence sales. The existing system must be revised to make licence data available following the end of the current fishing season.

A questionnaire program must be developed that has clear management objectives and data requirements and that specifically addresses the problems of nonresponse and recall bias. The program should deal specifically with the data required, the amount of respondent preparation and involvement required, the design of the questionnaire, pre-tests of the questionnaire, and the number and types of follow-up and motivational aides required. Filion (1980) has reviewed procedures to increase response and concluded that high response rates do not necessarily mean added costs but definitely provide important benefits. He pointed out that it costs no more to administer a well-designed questionnaire than a poorly designed one. The questionnaire program must also be designed to minimize and control the effects of recall bias. The major effort should be toward making the effects of the recall bias as constant as possible from one survey to the next. For example, the literature reviewed shows that recall bias is highly correlated with time. The mail questionnaire must, therefore, be administered consistently to minimize year to year variability. Hiett and Worrall (1977) and Kazes (1980) have provided data to judge the effects on accuracy of delaying the survey for different time periods beyond the fishing season. Consistency in design, administration, and interpretation will be the key factor in increasing precision and producing reliable trend information.

Finally, the analysis and interpretation program for the mail questionnaire date must make it abundantly clear that, until nonresponse and recall biases can be either eliminated or adjusted for, the mail questionnaire can only be used to monitor trends.

SITE-SPECIFIC DATA COLLECTION SYSTEMS

The basic statistics required to manage the recreational fishery are stock, catch, yield, effort, and catch per unit effort. This study has focused on methods of collecting statistics on the latter four. For a given fishery, let:

- D = Total number of days of the season
- d = Total number of days sampled per season
- N_j = Total number of users on day j, j = 1,2 ...d
- n_j = Total number of users sampled on day j, j = 1, 2 ...d
- h_{ij} = Number of hours user i used the fishery on day j
- k_{ijs} = Number of species s caught and kept by user i on day j
- r_{ijs} = Number of species s caught and released by user i on day j
- l_{ijs} = Number of species s used for a shore lunch by user i on day j

Utilizing the above, a census design for a given fishery should provide estimates for the following population parameters:

$$T = \sum_{ijs} (k_{ijs} + l_{ijs}) + x \sum_{ijs} r_{ijs}$$

where T = total harvest over the season for all species
x = mortality ratio for species s caught and released, and

$$E = \sum_{ij} h_{ij}$$

where E = total fishing effort for the season, and = T/E
C = harvest per unit effort.

similarily:

$$t = \sum_{ijs} (k_{ijs} + l_{ijs}) + x \sum_{ijs} r_{ijs}$$

where t = sample harvest for d days, and

$\bar{t}$ = t/d is the mean sample harvest, and

$$e = \sum_{ij} h_{ij}$$

where e = sample total fishing effort for d days, and

$\bar{e}$ = e/d

where $\bar{e}$ = sample mean fishing effort

It is useful to identify four distinct types of recreational fisheries for the purpose of obtaining census information on T, E, and C: remote-access lodge fisheries, limited-access day fisheries, multiple-access day fisheries, and extended-stay fisheries. These classifications differ with respect to the methods of utilization and, from a statistical view, the ability to enumerate and obtain information from

the total population of users at any point in time.

Lodge fisheries are controlled access fisheries where use must be by arrangement with a particular lodge or similar commercial enterprise. The total population of users can be identified at any point during the season by enumerating lodges within the study area and guests at each lodge.

Day fisheries with limited access are fisheries where virtually all users arrive and depart the same day. The number of access points is small enough to allow continuous monitoring on any chosen day; however, monitoring throughout the season is not practical. The population of users for a given lodge fishery can, therefore, be measured for the entire fishing season, whereas it is only practical to measure the population of users for a limited-access day fishery on a sample of days.

For the remaining two classifications, it is not practical to obtain information from the total population of users at any point in the season. The number of access points for multiple-access fisheries is too large to allow for continual monitoring, and extended-stay fisheries require complete coverage on any given day or continual monitoring of all access points throughout the season to obtain information on the total population of users.

Remote-access lodge fisheries

Total population information can usually be obtained from lodge fisheries because access to such fisheries is completely controlled. A total census requires the cooperation of the lodge managers, the individual guides and, of course, the users. The basic data collection system we suggest for the lodge fisheries is a modification of the Tidal Sportfishing Diary suggested by MacGregor (1982). In this system each user records his effort and success in a logbook from which a duplicate carbon copy is collected at the end of each day. As an incentive to participate, the users will be allowed to retain the original log books as a record of their fishing trip. The basic information to be collected in the log books is that needed for computing T, E, and T/E, although additional biological information such as fish lengths or weights may also be collected depending on specific management or research requirements.

One person on the lodge staff should be paid extra to supervise the data collection program. This person will distribute the logs, provide instructions to the guides, monitor the progress of the program, and collect the logbook carbons each day.

The guides will be responsible for reminding users to maintain up-to-date and accurate log books, and for conducting periodic, informal accuracy checks. With the cooperation of the lodge manager, it is hoped that these minimal tasks can be incorporated as part of the guide's regular duties and will not require additional incentives.

This lodge fishery data collection system is designed to obtain total population information so that statistical inference calculations (e.g., standard errors) should not be needed. One possible complication, however, is that some of the required information will be missing. For example, individual users may fail to turn in a particular day's log or may record only partial information on a few catches. If the amount of missing data is small, standard imputation methods can be used. On the other hand, if considerable data is missing, appropriate statistical methods will have to be developed to obtain population estimates and assess their accuracy.

Establishing statistical methods at this point in the design of the reporting system to cover all possible patterns of missing data would be costly and premature. Instead, the likely patterns of missing data should be determined through a one-year pilot program that should be designed to test and refine the basic methodology.

Limited-access day fisheries

In this category of fishery, complete information on a single day's fishing activities can be obtained by a creel census that involves stationing interviewers, possibly in shifts throughout the day, at the access points to the fishery. As users leave the fishery, the interviewer will record the access point identification, the fishery identification, the date, and, for each user, the total number of fish kept, the number used for shore lunch, the number caught and released, and the total fishing time.

Because fishing pressure is known to vary in some areas, depending on the day of the week, it is desirable to stratify the sampling units (days) into two strata, where s_1 = weekdays and s_2 = weekend days and holidays. The required information should be collected on a random sample of d_i days from stratum s_i, where $i = 1, 2$. Depending on the length of the season and the relative number of users in s_1 and s_2, it may be desirable to sample s_2 exhaustively since the fishing pressure in s_2 will likely be much greater than that in s_1. Estimates of T, E, and T/E can be obtained by using standard methodology (Cochran 1977). Let D_i denote the total number of days in stratum s_i; let $f_i = d_i/D_i$, the sampling fraction for stratum s_i, and let $w_i = D_i/D$, the weight for stratum i for $i = 1, 2$. The total harvest T for the fishery is estimated as:

$$\hat{T} = \sum_i \frac{1}{f_i} \left(\sum\sum\sum_{ijs} (k_{ijs} + l_{ijs}) + x \sum\sum\sum_{ijs} r_{ijs} \right)$$

$$= \sum_i^2 D_i \bar{t}_i$$

where $\bar{t}_i$ is the average harvest for stratum s_i for $i = 1, 2$.

The estimated variance of T is:

$$\hat{V}(\hat{T}) = \sum_i D_i (D_i - d_i) s^2_{t_i}/d_i$$

where

$$s^2_{t_i} = \frac{1}{d_i - 1} \sum_j^{d_i} (t_{ij} - \bar{t}_i)^2$$

and t_{ij} is the total harvest on day j in stratum i.

Similarly, the estimate for total effort E is:

$$\hat{E} = \sum_i D_i \bar{e}_i$$

where $\bar{e}_i$ is the mean effort over sampled days in stratum i, (total effort over all users and days) E/d_i for i = 1, 2, and the estimated variance of E is:

$$\hat{V}(\hat{E}) = \sum_i D_i (D_i - d_i) s^2_{e_i}/d_i$$

where

$$s^2_{e_i} = \frac{1}{d_i - 1} \sum_j^{d_i} (e_{ij} - \bar{e}_i)^2$$

where e_{ij}, is the effort over all users on day j in stratum i.

The simplest estimates of C, the harvest per unit effort, is

$$\hat{C} = \hat{T}/\hat{E}$$

The estimated variance of C is

$$\hat{V}(\hat{C}) = \frac{1}{\hat{E}^2} \sum_i \frac{D^2_i (1 - f_i)}{d_i} \times (s^2_{t_i} + \hat{C}^2 s^2_{e_i} - 2 \hat{C} s_{te_i})$$

where

$$s_{te_i} = \frac{1}{d_i - 1} \sum_j^{d_i} (t_{ij} - \bar{t}_i)(e_{ij} - \bar{e}_i)$$

is the sample covariance between harvest and effort in stratum i.

Since information on three population parameters is required, the determination of optimal sample size and allocation will depend on the relative variance of effort, harvest and harvest per unit effort in each stratum. In any case, it is reasonable to assume that the daily cost of sampling is constant across strata. If harvest is of primary importance, the optimal allocation for a fixed sample size d is estimated using

$$d_i = d\, D_i s_{t_i} / \sum_j D_j s_{t_j} .$$

Assuming optimal allocation, the total sample size required to achieve a specified value V_o for V(T) is estimated by

$$d = [\sum_j w_i s_{t_i}]^2 / (V_o + \frac{1}{D} \sum_i w_i s^2_{t_i})$$

These estimates can be adapted for E by replacing s_{t_i} by s_{e_i}, i = 1, 2. In either case, prior estimates s_{t_i} and s_{e_i} of the stratum standard deviations are required from prior information or pilot study data.

Multiple-access day fisheries and extended-stay fisheries

These are the most difficult types of fisheries to census because of the difficulty in identifying the population of users at any point in the season. The suggested method is to conduct two separate censuses to obtain direct, independent estimates of E and C = T/E, and then use the product of these as an estimate of T.

The effort census: The sampling unit for the effort census is a time by space unit. The temporal component is taken to be one hour of a 16-hour fishing day. The spatial component will depend on the characteristics of the fishery in question but it should be constructed so that it can be censused in a single hour. In this case, a unit census is simply a count of the number of users in a spatial component during a one-hour temporal component. It is assumed that the population of users is relatively stable during each one-hour unit. In other words, if n users are identified in a particular spatial unit during a one-hour temporal unit, then these users contribute n hours of effort to the total. With this structure, total effort is equivalent to population size.

For the effort census, it is desirable to stratify in both space and time. The spatial strata will depend on the particular fishery, but the areas close to high-use access points are natural candidates for stratification. The temporal strata should be constructed based on weekday and time of day. Four-hour blocks, starting at 0600h and ending at 1100h, are good candidates for time of day strata, since fishing pressure is usually highest during the early and late parts of the day.

As an example, suppose that a particular fishery has 10 high-use access points and 5 low-use access points. The areas around these 15 access points comprise the spatial units which are divided into two strata consisting of the 10 high-use points and the 5 low-use points. Suppose further that the season lasts 10 weeks so that there are 50 weekdays and 20 weekend days. There are then 8 temporal strata. The first 4 consist of consecutive four-hour blocks of time across the 50 weekdays, with each stratum containing 4 x 50 = 200 possible hours to be sampled. The second four strata consist of four-hour blocks of time

across the 20 weekend days, with each stratum containing 4 x 20 = 80 hours. In total there are 2 x 8 = 16 time-space strata. One stratum consists of the time period 0600h-1000h on weekdays at the high-use access points. The same stratum contains 4 hours x 50 days x 10 access points, or 2,000 time-space sampling units. A random sample of size 30 from the strata would require 30 hours of sampling, each hour in the period 0600h-1000h, across 50 possible weekdays and 10 access points. A single sample might require a count of all users around the fourth high-access point from 0900h to 1000h on the third Tuesday of the season. For stratum i, let

N_i = Total number of time-space units
n_i = sample size
N = sum of N_i
W_i = N_i/N Stratum weight
y_{ij} = Total number of users observed in the j-th unit, j=1, 2...n_i
f_i = n_i/N_i

The estimate of total effort for the fishery is then

$$\hat{E} = \sum_i N_i \bar{y}_i$$

where

$$\bar{y}_i = \sum_j y_{ij}/n_i$$

the estimated variance of E is

$$\hat{V}(\hat{E}) = \sum_j N_i(N_i - n_i)\, s^2{}_i/n_i$$

where

$$s^2{}_i = \frac{1}{n_i - 1} \sum_j (y_{ij} - \bar{y}_i)^2$$

Sample size and optimal allocation are determined according to the procedure outlined for surveys of limited-access day fisheries.

Harvest per unit effort censuses: The proposed census for estimating C is the same as that for limited-access day fisheries except that access points will have to be sampled rather than covered exhaustively. To understand this census, consider the example used for the effort survey. There are four strata: high-access points on weekdays, high-access points on weekend days, low-access points on weekdays, and low-access points on weekend days. In this case, the temporal component of a sampling unit is a day and the spatial component is an access point. The four strata listed above contain 10 x 50 = 500, 10 x 20 = 200, 5 x 50 = 250 and 5 x 20 = 100 sampling units, respectively. A unit is measured by stationing interviewers, possibly in shifts, at the corresponding access point for a full day and collecting the information as indicated for limited-access day surveys. Of course, sampling units are to be randomly selected within strata.

The harvest per unit effort, C, is estimated along with its variance by defining y_{ij} to be the total harvest per unit effort for day j in stratum i and following the expressions for E and V (E) given for the effort census. Again, sample size and optimal allocations are determined as outlined for limited-access day fisheries.

Total harvest: With the estimates from the effort and harvest per unit effort surveys, the total harvest T can be estimated by

$$\hat{T} = \hat{E}\hat{C}$$

For unexploited fisheries, the estimated variance of T is approximated by

$$\hat{V}(\hat{T}) = E^2\hat{V}(\hat{C}) + \hat{C}^2\hat{V}(\hat{E})$$

where C and E are independent, and for exploited fisheries

$$\hat{V}(\hat{T}) = \hat{E}^2\hat{V}(\hat{C}) + \hat{C}^2\hat{V}(\hat{E}) + 2\hat{C}\hat{E}\,\hat{cov}\,(\hat{C},\hat{E})$$

where C and E are not independent, and where $\hat{V}(\hat{E})$ and $\hat{V}(\hat{C})$ are obtained from the effort and harvest per unit effort surveys.

As an alternative to the surveys proposed above, a roving creel census might be used to obtain an estimate of harvest per unit effort. However, this assumes that the harvest rate is constant throughout the day. Malvestuto and Davies (1978) indicate that this assumption might be acceptable, but Robson (1960, 1961) suggests the opposite may be true. In view of the uncertainty involved, it seems most reasonable to adopt a census method that does not require such an assumption.

Estimates of sample size and optimal allocation for the various surveys require information on stratum variances. Because such information is lacking, it will be necessary to rely on the results of pilot runs to establish the final census protocol.

The results from the harvest per unit effort census for multiple-access day fisheries and extended-stay fisheries can be used to obtain estimates of T and E in addition to C. This is done by using the estimation methods for limited-stay fisheries modified to allow for additional strata over access points. However, a bias may be introduced because of users who do not arrive and depart the same day. As a very extreme case, a user who arrives the day before the season begins and departs the day after the season ends will have a zero probability of being included in any sample. The effort census is intended, in part, to allow for such possibilities. It will, however, be of interest to compare estimates of T and E obtained from just the harvest per unit effort with those obtained using the procedure detailed above. It is possible that the effort census may not be necessary for certain multiple access fisheries.

RECOMMENDATIONS FOR FURTHER STUDIES

The previous section describes a three-tier statistical reporting system to provide

recreational fisheries data for the NWT. Four different data collection systems were recommended and described.

These data collection systems were recommended on the basis of their ability to provide the required information with a minimum of cost and effort. Each of the systems described have some flexibility in their exact application. Since there is no previous operating experience with these systems, their costs and statistical effectiveness will have to be determined through pilot programs. We recommend that such pilot programs be developed and conducted in 1983 to evaluate each of the recommended systems.

The unstructured field checks and reports are the most cost-effective method of collecting general information on the extensive fisheries. The existing program should be reviewed and evaluated for its contribution to the reporting system, data requirements should be defined, and a consistent reporting system developed.

The design of the questionnaire program and its administrative system should be initiated immediately because of the lengthy administrative lead times required. A computerized mailing, editing, and analysis program should be considered to improve the quality of the product and minimize labor requirements. Because of the relatively small number of recreational fishermen involved, consideration should also be given to maintaining, as part of the computerized system, a data base to provide additional data on the demography and user characteristics of the recreational fishermen.

The diary system should be tested on at least two lodges, one at Great Bear Lake and one at Great Slave Lake. The test lodges should be medium to large and should have a maximum mixture of species available for catch. The test program should consist of the following items:

- identify specific biological and economic data requirements for the pilot program;
- develop implementation logistics with experienced field staff;
- draft proposed program and discuss with lodge owners at their annual fall meeting;
- develop data forms and accompanying educational materials
- test program on lodges during 1983 season;
- analyze results and develop imputation or statistical techniques to account for any missing data, and
- evaluate the cost and effectiveness of the program, and modify as required for implementation.

The creel census should be tested on at least two road-access fisheries. One of these fisheries should be a limited-access type and the other should be a multiple-access type. It would be preferable to select road-access fisheries that had a maximum mixture of species available for catch. The test program should consist of the following items:

- identify specific biological and economic data requirements for the pilot program;
- identify and characterize the road access fisheries in the NWT and select one limited-access and one multiple-access fishery for the pilot program;
- develop implementation logistics with experienced field staff;
- develop data forms and accompanying educational materials;
- test creel census methods during the 1983 season;
- analyze results, test assumptions, and develop sample size and allocation of effort for future surveys, and
- evaluate the cost and effectiveness of each survey, and modify as required for implementation.

The recommended systems are designed primarily to provide yield and effort data that can be used for both biological and economic analyses of the recreational fishery. If additional data are required to provide estimates of the value of specific lodge fisheries, site-specific surveys will be required to collect the data. If additional data are required to provide estimates of the value of specific road-access fisheries, the surveys whould be conducted in conjunction with creel censuses. Combining these surveys will have the advantage of sharing a previously designed sampling scheme, providing consistent results, and sharing manpower and costs.

If additional biological or economic data are required for intensive/extensive fisheries, the mail questionnaire system may be appropriate. This information should be collected through a special questionnaire, since adding questions to existing questionnaires could reduce the quality and consistency of the existing data collection program.

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Table 1. Examples of lakes and rivers in each fishery category in the NWT (data supplied by R.W. Moshenko, personal communication).

FISHERY	FISHERY TYPE
Intensive Fisheries	
Great Slave Lake	road access, lodges
Great Bear Lake	remote access, lodges
Hay River	road access
Mosquito Creek	road access
Marian Lake	Boat access, winter access
Kasba Lake	road access
Kakisa Lake	road access
Dolomite Lake	road access
Campbell Lake	road access
Sylvia Grinnell River	road access
Tree River	remote access
Prelude Lake	road access
Prosperous Lake	road access
Intensive/Extensive Fisheries	
Gordon Lake	winter road access, lodge
Sitidgi Lake	remote access
Hornaday River	remote access, road access
Contwoyto Lake	remote access
Dubawnt Lake	remote access, lodge
Nueltin Lake	remote access, lodge
Nonacho Lake	remote access, lodge
Kasba Lake	remote access, lodge
Snowbird Lake	remote access, lodge
Yathkyed Lake	remote access, lodge
Henik Lake	remote access, lodge
Robertson River	remote access, lodge
Back River	remote access
Stanwell-Fletcher Lakes	remote access
Kingnait Fiord	remote access
Pangnirtung Fiord	remote access
Extensive Fisheries	
All other lakes	predominantly remote access

Table 2. Summary of reporting methods used for evaluating fish harvest in the Western United States[1] (from Aney 1974).

Species	Unsupervised Field Checks	Sample Surveys			Report Forms	Diaries	Check Stations	Other[2]
		Field	Mail	Home				
Cold-Water	12	12	8	2	2	3	1	0
Warm-Water	11	9	7	2	2	3	1	0
Anadromous	5	3	5	1	3	0	1	1
Marine	1	4	2	0	0	0	0	1

[1] Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming.
[2] Fish passage counts and party boat logs.

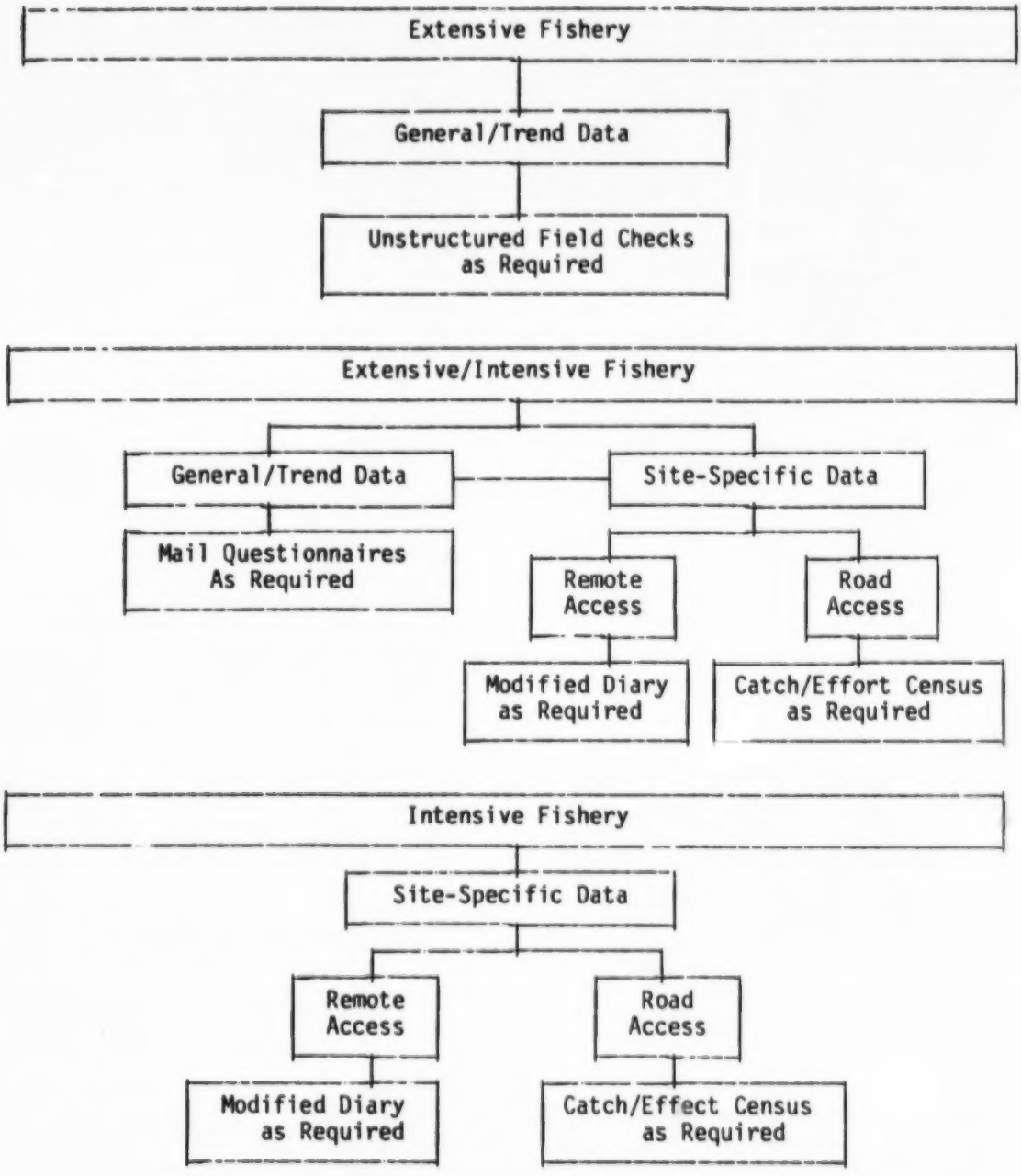

Fig. 1. Schematic of a statistical reporting system for the sport fishery of the NWT.

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